ASSESSMENT OF CALOOSAHATCHEE DESIGN ELEMENTS IN THE RESTUDY AND LEC PLAN USING REVISED CALOOSAHATCHEE HYDROLOGY[1]

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SUMMARY

Recent hydrologic studies done for the *Caloosahatchee Water Management Plan* (CWMP) show less runoff and more demand in the Caloosahatchee Basin, as compared to estimates used in the *Lower East Coast Regional Water Supply Plan* (LEC Plan). These changes affect the LEC Plan by greatly reducing the available water in the basin. This memorandum describes an assessment of the performance of the reservoir - ASR - backpumping facilities proposed by the LEC using revised Caloosahatchee hydrology. In this analysis it was assumed that water supply releases from Lake Okeechobee to the Caloosahatchee Basin are restricted to 29,000 acre-foot per year. The study finds the following:

1. The proposed facilities would only provide a 1-in-3 level of drought protection for the 175,000 acres of irrigated land anticipated in the CWMP 2020 scenario
2. The proposed facilities could provide a 1-in-10 level of drought protection for 120,000 acres of irrigated land
3. By increasing the reservoir capacity to 220,000 acre-foot, the proposed facilities could provide a 1-in-10 level of drought protection for the 175,000 acres of irrigated land anticipated in the CWMP 2020 scenario
4. Backpumping to Lake Okeechobee may not be practical under the assumptions in some 2020 scenarios, but remain a viable option in others

BACKGROUND

Motivation for the CWMP Reassessment of Caloosahatchee Hydrology

During the development of the Lower East Coast Water Supply Plan (LEC Plan) it was determined that there was a need to reassess the estimates of Caloosahatchee runoff and demands used in water supply modeling. This is important to the LEC Plan because

1. This document is from the Caloosahatchee Water Management Plan. With the exception of this footnote, no changes have been made.

agricultural stakeholders believed that 2020 demand estimates for the Caloosahatchee needed to be reanalyzed.

Previous demand and runoff estimates (Trimble) were developed from reliable flow data but the lack of reliable information on land use, in particular land use within the Lake Okeechobee Service Area (LOSA), made estimates of future demands problematic. Consequently, the Caloosahatchee Water Management Plan (CWMP) was tasked with reassessing the hydrology in the Caloosahatchee.

This reassessment has been completed. (Konyha and Flagg; draft) (Owasina, Dabbs and Jansen; draft). This reassessment is based on more detailed land use information and a determination of surface irrigated lands in LOSA. The reassessment uses deterministic hydrologic modeling of all lands in the watershed over a 31-year period. The source of irrigation water (groundwater or C-43 water) is considered in the analysis. The new estimates of runoff and demands are substantially different from the earlier estimates. They show substantially less available water (i.e. runoff minus demands) in the Caloosahatchee Basin than was assumed in the Restudy and initial runs of the LEC Plan. A comparison of the two estimates is shown in **Table I-8**. The estimate of 2020 demands has increased by 67,000 acre-foot per year (+53%) while the estimate of runoff has decreased by 143,000 acre-foot per year (-18%).

Table I-8. Comparison of Average Annual Demand and Runoff from the East and West Caloosahatchee Basin (1965-1995 Climate).[a]

	Old Estimates (used in Restudy and LEC PLAN)		New Estimates (used in CWMP)	
	Demand	**Runoff**	**Demand**	**Runoff**
1995 Land use	89,518	814,883	112,449	674,711
2020 Land use (LEC Plan)	111,000	814,937	192,253	671,689
2050 Land use (RESTUDY)	125,334	814,937	---	---

a. Units are acre-foot per year

The new estimates of runoff (670,000 acre-foot per year) are not substantially different from 1972-1995 measured basin runoff (650,000 acre-foot per year). Approximately half of the differences in demands are caused by revisions in future land use and half result from methodological differences. The revised estimates are preferred over the previous estimates.

Potential Impact of the Revised Hydrology on Existing Restudy Design Elements

To date, Restudy and LEC Plan analyses have had to rely on the old estimates in their modeling efforts. The changes in runoff and demand are large and may affect the performance of the design components being recommended by the LEC Plan. This study assesses the performance of Restudy Design Elements for the Caloosahatchee using the new estimates of demand and runoff developed by the CWMP.

Summary of Existing Restudy Design Elements

The Restudy has proposed a development of local water resources to reduce the basin's reliance on Lake Okeechobee waters. Local water resources would be developed using three methods: a regional reservoir, a set of aquifer storage and recovery (ASR) wells, and a set of pumps to lift local runoff water back into Lake Okeechobee. A brief description of these three design elements follows.

<u>Reservoir</u> - The reservoir is 10,000 acres in area with a 16-ft depth and a capacity of 160,000 acre-foot. Waters are pumped from the C-43 Canal into the reservoir using a pump with 2,500 cfs capacity. The reservoir is located in the West Caloosahatchee Drainage Basin. The operating rules for the reservoir are based on reservoir storage and basin runoff.

<u>ASRs</u> - There are 22 sets of Aquifer Storage and Recovery wells each with a capacity of 10 mgd (220 mgd total capacity). These inject waters from the reservoir or withdraw waters from the ASRs. A 75% recovery is assumed regardless of the period stored underground. It is assumed that there is no mixing with higher salinity aquifer water. The operating rules of the ASRs are based on reservoir storage.

<u>Backpumping</u> - A set of pumps near the S-78 Structure lift waters from the reservoir and the West Caloosahatchee Basin into the East Caloosahatchee Basin. A second set of pumps lift waters from the East Caloosahatchee Basin through a storm-water treatment area into Lake Okeechobee. The pump capacity of these facilities is 1,000 cfs. Operating rules for the pumps are based on the reservoir storage volume.

> Note: These are generic design elements that may be replaced by alternate design elements in the future. For example, the number of reservoirs, their location(s), the size of AS’s, or the development of well-fields in lieu of reservoirs are all potential alternatives to the generic design elements discussed here. All are consistent with this analysis in the sense that all develop the local water resource.

PROBLEM STATEMENT

This paper assesses the performance of the proposed Reservoir - ASR - Backpumping facilities using the revised estimates of Caloosahatchee Basin runoff and demands. The assessment asks three questions: how well would the system perform; how much land could the system adequately irrigate; and what size reservoir would be needed to provide adequate irrigation?

Assessment #1: Describe the performance of the existing Restudy Design Elements.

The objective of this assessment is to determine the level of service that would be provided by the Restudy Design Elements as described above. Because runoff has decreased and irrigation has increased, the level-of-service will be below the desired 1-in-10. Because there is competition between irrigation demands and estuarine needs it is assumed, a priori, that estuarine needs will be met even though irrigation demands are not met.

Assessment #2: Determine the maximum irrigated land area that could be supplied at a 1-in-10 level of service using the existing Restudy Design Elements

The objective of this assessment is to determine the acres of land that can be irrigated by the C-43 while still meeting the desired 1-in-10 level of service and also meeting estuarine needs.

Assessment #3: Determine the reservoir size needed to meet revised CWMP 2020 demands with a 1-in-10 level of service.

The goal of the LEC Plan is to achieve a 1-in-10 level of service for all anticipated future water supply needs. This objective of this assessment is to describe one method of meeting that requirement. For the purpose of this study the size of the reservoir will be increased until both water supply demands and estuarine needs can be met.

METHODOLOGY

Modeling Approach

A computer model called OPTI-5 is used for these analyses. The model determines operational rules for storage/release systems (i.e. reservoir, ASRs, and backpumping facilities). The goal of the model is to find operational rules that simultaneously supply the irrigation demands in the basin and also meet the environmental criteria for the Caloosahatchee Estuary. This type of model is well suited for situations where there is competition for a resource. In this case the competition is between human demands and estuarine needs and the resource is watershed runoff. This model was written for the District under contract by John Labadie (1997).

The Caloosahatchee Optimization model requires three operational rules: a reservoir rule, an ASR rule, and a backpumping rule. The operational rule for the reservoir describes when water is pumped to/from the reservoir and how much is pumped. The operational rule for the ASRs describes when ASR water is injected/withdrawn. The operational rule for backpumping describes when and how much water is withdrawn from the reservoir and sent back to Lake Okeechobee.

The model uses a Genetic Algorithm to select the operational rules, testing the performance of the system using a 31-year period of runoff and demands. The performance is tested using two performance measures: one for water supply, and one for estuarine needs. Many different rules are generated and tested. In this exercise, the Optimization model generated and tested 30,000 different sets of rules for each simulation. Each simulation takes about two hours using a high speed PC.

Performance Measures and Targets

Level of Service for Water Supply

The performance measure for water supply is the level of service and the desired water supply target is a 1-in-10 level of service. The level of service (l.o.s.) is defined as:

l.o.s. = (years when all supplies are met)/(years simulated)

Because the model simulates 31 years of watershed behavior, the 1-in-10 criteria is met if the system can provide all water demands for twenty-eight of the thirty-one years simulated (l.o.s. = 28/31 = 0.9). The model also tracks demands unmet. This performance measure is equivalent to one used in the LEC Plan planning process.

Estuary Protection Criteria

Estuary Performance Measure

The performance measure for estuarine protection is the distribution of monthly flows to the estuary. The monthly flow distribution is determined by calculating the average monthly flow for each month simulated and then counting the number of occurrences in selected flow ranges. This measure only has value if a sufficiently long period of climate is simulated. The period of record for these simulations is 31 years.

Estuary Performance Targets

The performance of a model is determined by comparing the modeled flows to the estuary (the performance measure) against a target flow distribution. The target flow distribution for the Caloosahatchee Estuary is presented in**Table I-9**

Any simulation that has fewer than 60 months of flows below 300 cfs, and fewer than 22 months of flows between 2800 and 4500 cfs, and fewer than 6 months of flows above 450 cfs meets the estuary performance target. This performance target is identical to that used in Restudy and the LEC PLAN. The performance target was developed by biologists studying the estuary (Chamberlain et. al, 1998) and is based on the frequency of harm experienced by sea-grasses in a natural system. This 'natural' flow is log-normally

Table I-9. Target Flow Distribution (31 year period)

Flow Range	Frequency Distribution (percent)	Number of Occurrences	Problem Caused
0 to 300 cfs	16	<60	High salinity damages freshwater tolerant seagrasses
300 to 2,800 cfs	76	284	None
2,800 to 4,500 cfs	6	<16	Low salinity damages saltwater tolerant seagrasses in estuary
> 4,500 cfs	2	<6	Low salinity damages seagrasses outside estuary (where salinity is normally >30 ppt)

distributed and represents an average annual flow of about 650,000 acre-foot per year. This volume is equal to the average 1965-1995 basin runoff.

Estuary Modeling Targets

The flow distribution targets used in the optimization model are not the same as the performance targets above. If performance targets were used, they would force the model to provide an average flow of 650,000 acre-foot per year to the estuary. However, the estuarine ecosystem does not need this much water. The undeveloped watershed probably had at least 100,000 acre-foot less runoff than today's watershed (4 inches more evapotranspiration from the 250,000 acres of former wetlands and forest that are now pasture and grazing lands). Biologists have made an evaluation of minimal flows required by Caloosahatchee watershed (Haunert, Doering, and Chamberlain - draft) that shows that a much smaller volume of water could meet estuarine needs - if the distribution of the flow remained log-normal. This modeling target distribution is shown in **Table I-10**.

This distribution is used in all optimization modeling in this paper. This is also the distribution used in developing the Restudy Recommended Plan (Alt D13R) and the preferred LEC Plan. This distribution of flow represents an average annual flow of about 450,000 acre-foot per year. The difference between the measured basin runoff (650,000 acre-foot per year) and this minimal flow distribution (450,000 acre-foot per year) defines the water available in the watershed for development. This available water (200,000 acre-foot per year) is roughly equivalent to the proposed 2020 demands from the C-43 Canal (192,000 acre-foot per year). It is this water that is captured by the reservoir-ASR-backpumping system and redirected to meet water supply needs.

Table I-10. Modeling Target Flow Distribution (31-year period).

Flow Range	Frequency of Occurrence (percent)	Number of Occurrences
0 to 300 cfs	10	37
300 to 660 cfs	55	205
660 to 925 cfs	20	74
925 to 1,550 cfs	10	37
1,550 to 2,175 cfs	3	11
2,175 to 2,800 cfs	2	6
2,800 to 4,500 cfs	1	2

Assumptions Made in These Simulations

In the time frame available, it was not possible to assess all of the potentially viable methods of providing the additional irrigation water supply. Therefore the following assumptions were made:

- Lake Okeechobee deliveries are held constant and equal to the deliveries of the SFWMM simulation called 'sfwmm_2020wr'. This simulation provides about 30,000 acre-foot per year from the lake for irrigation in the C-43 Basin.
- ASRs are not expanded. The capacity of the aquifer storage and recovery wells is kept at 220 mgd.
- Estuarine protection criteria will not be changed. Further, protection of the estuary will be given priority over water supply criteria.
- Increased demands will be met through expansion of the regional reservoir.
- For the purpose of this analysis it is acceptable to reduce backpumping. Any impact of reduced backpumping on the regional system is not considered in this analysis.

ASSESSMENTS

Assessment #1: Describe the Performance of the Existing Restudy Design Elements

This analysis examines the performance of the Caloosahatchee system using the revised runoff and demand data while keeping the reservoir capacity at 160,000 acre-foot. Other Restudy Elements are also unchanged. The object of this analysis is to determine what level of drought protection can be provided and also to determine if the estuary protection criteria can be met.

Drought Protection Performance

The assessment shows that, with the revised demands, the proposed 160,000 acre-foot reservoir will not be able to meet demands at a 1-in-10 level of service. The lake provides 29,000 acre-foot per year of the total 192,000 acre-foot per year, leaving 163,000 acre-foot of demands for the basin. The existing system can provide 138,000 of (85%) this demand but the timing of these deliveries (**Table I-11** and **Figure I-4**) are such that the basin goes into water shortage on 13 of the 31 years, giving a projected level of service of only 58%.

Table I-11. Average Annual Demands and Supplies and Level of Service.

Total C-43 Demands (acre-foot per year)	Lake Supplies (acre-foot per year)	Local Supplies (acre-foot per year)	Demands Unmet (acre-foot per year)	Level of Service (percent)
192,253	29,241	137,610	25,401	58

Estuarine Performance

The assessment shows that the proposed system can still meet environmental flow targets. However, the OPTI-5 model found backpumping to be ineffective in meeting estuarine performance targets. Backpumping was modeled as a process in the OPTI-5 model but the model decided that the best way to use the water was by turning backpumping off. The model's decision to not use backpumping is due in part to the modeling assumption that backpumped waters would not be used to meet future water supply needs. In the past, backpumping was effective because there was considerably more available water in the basin and backpumping could reduce the number of high flow months. With the higher demands and lower runoff estimates used in this analysis there is too little excess water to backpump.

Table I-12 and **Figure I-5** show the distribution of monthly flows for the new hydrology (2020 Base) and for the system with the existing Restudy elements. Low flows have been increased and high flows decreased.

Table I-12. Estuarine Flows and Distribution.

2020 Base Runoff (acre-foot per year)	Runoff with Restudy Elements (acre-foot per year)	Backpumping Volume (acre-foot per year)	Flow Distribution		
			<300 cfs	2,800-4,800 cfs	>4,800 cfs
769,124	593,230	0	66	16	7

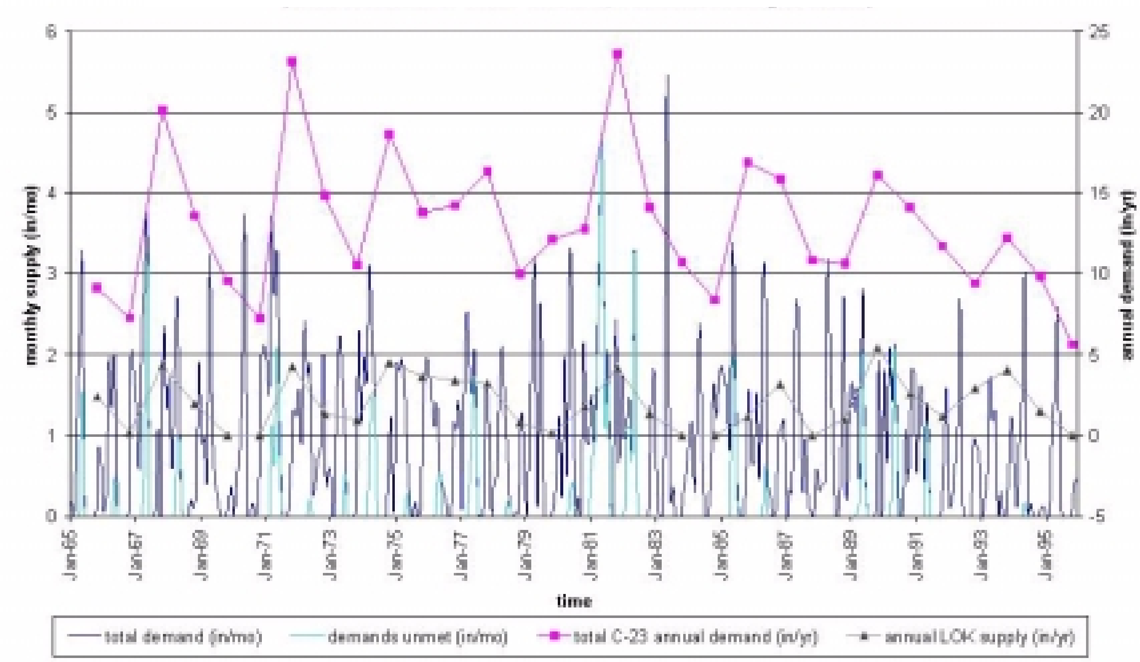

Figure I-4. Drought Protection Performance for Assessment #1.

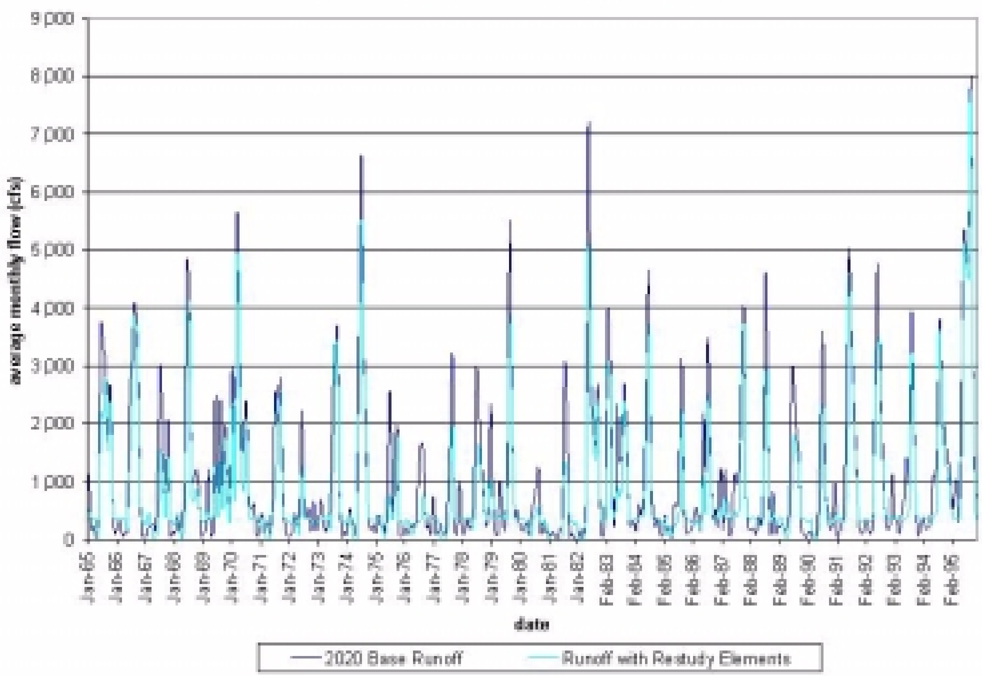

Figure I-5. Estuarine Performance for Assessment #1.

Assessment #2: Determine the Maximum Irrigated Land Area Supplied at a 1-in-10 L.O.S. with the Existing Restudy Design Elements

In the second assessment, the reservoir size is kept at 160,000 acre-foot and the irrigation demand is reduced until a 1-in-10 level of service can be maintained. This required several simulations as the irrigation demands were varied; only the final, acceptable, run is described here.

Drought Protection Performance

This assessment found that the existing Restudy Design Elements could supply (at a 1-in-10 l.o.s.) an irrigation demand of about 135,000 acre-foot per year (29,000 from the Lake and 101,000 from the basin) (**Table I-13**). This compares to a 1995 C-43 demand of 112,000 acre-foot per year and a 2020 demand of 192,000 acre-foot per year. This is roughly equivalent to 120,000 acres irrigated by the C-43 Canal and compares to 103,000 acres irrigated by the C-43 in 1995 and a projected 177,000 acres irrigated by the C-43 in 2020.

Table I-13. Average Annual Demands and Supplies and Level of Service.

Total C-43 Demands (acre-foot per year)	Lake supplies (acre-foot per year)	Local supplies (acre-foot per year)	Demands Unmet (acre-foot per year)	Level of Service (percent)
135,350	29,241	100,640	5,469	87

Estuarine Performance

The assessment shows that the proposed system can still meet environmental flow targets. In this case, the OPTI-5 model found 58,000 acre-foot per year of water available for backpumping. Backpumping occurs on 112 of the months in the simulation (about 2 months per year) and seems to be effective in reducing estuarine flows during high flow months, thus allowing the reservoir to be utilized for water supplies. If flows from the Lake were allowed to increase as a result of this backpumping, a larger acreage could be supported by this reservoir.

Table I-14 and **Figure I-6** show the distribution of monthly flows for the new hydrology (2020 Base) and for the system with the existing Restudy elements. Low flows have been increased and high flows decreased. Backpumping is also shown on this figure.

Table I-14. Estuarine Flows and Distribution.

2020 Base Runoff (acre-foot per year)	Runoff with Restudy Elements (acre-foot per year)	Backpumping Volume (acre-foot per year)	Flow Distribution		
			<300 cfs	2,800-4,800 cfs	>4,800 cfs
769,124	582,988	58,323	49	15	5

Assessment #3: Determine the Reservoir Size Needed to Meet Revised CWMP 2020 Demands with a 1-in-10 L.O.S.

In this assessment, demands are set equal to the revised 2020 demands (192,000 acre-foot per year) and the size of the reservoir is increased until a 1-in-10 l.o.s. is achieved. This required several simulations but only the final run is described here.

Drought Protection Performance

The assessment found that a 220,000 acre-foot reservoir was needed to provide water supplies at a 1-in-10 level of service. **Table I-15** and **Figure I-7** show the performance of this system.

Table I-15. Average Annual Demands and Supplies and Level of Service.

Total C-43 Demands (acre-foot per year)	Lake supplies (acre-foot per year)	Local supplies (acre-foot per year)	Demands Unmet (acre-foot per year)	Level of Service (percent)
192,253	29,241	154,945	8,056	90

Estuarine Performance

The modified system can also meet the estuarine performance targets. Although the performance shown in **Table I-16** is marginal, it is believed that minor additional modifications of the OPTI-5 model parameters would provide an acceptable performance. (Lack of time precluded these additional modifications). The high demands decrease available water in the basin and therefore (as with assessment #1) the OPTI-5 model found backpumping to be ineffective under the assumptions modeled.

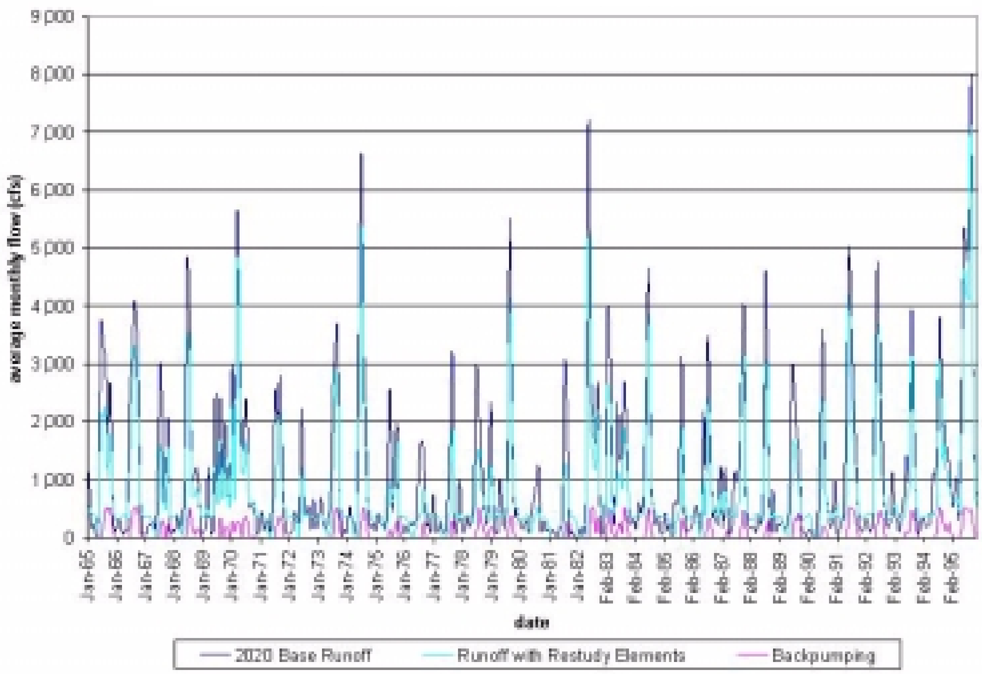

Figure I-6. Estuarine Performance for Assessment #2.

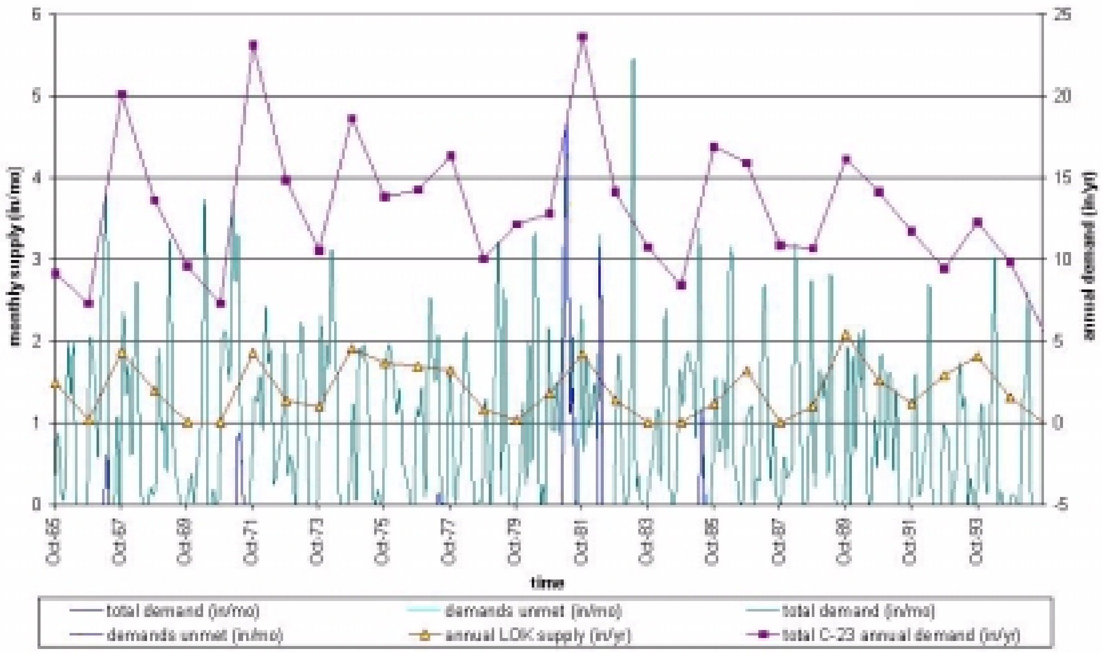

Figure I-7. Drought Protection Performance for Assessment #3.

Table I-16. Estuarine Flows and Distribution.

2020 Base Runoff (acre-foot per year)	Runoff with Restudy Elements (acre-foot per year)	Backpumping Volume (acre-foot per year)	Flow Distribution		
			<300 cfs	2,800-4,800 cfs	>4,800 cfs
769,124	570,466	0	64	20	6

Table I-16 and **Figure I-8** shows the distribution of monthly flows for the new hydrology (2020 Base) and for the system with the larger reservoir. These flows are similar to those of assessment #1 and assessment #2.

CONCLUSIONS AND RECOMMENDATIONS

Description of One Water Management System That Satisfies Environmental and Water Supply Performance Measures

The above analyses show that approximately 60,000 acre-foot of additional storage may be needed for the Caloosahatchee Basin. Expanding the proposed 160,000 acre-foot reservoir to 220,000 acre-foot will provide this storage. Optimization modeling shows that this modification would result in a system capable of meeting both water supply needs and the environmental needs of the estuary.

Recommendations for Future Work

Expansion of the reservoir is only one solution; it is not necessarily the best solution. There are other ways to develop local water resources (increased use of groundwater, distributed reservoirs, backpumping to Lake Okeechobee, etc.) and these options should be explored.

The three assessments produce very similar outflow volumes (593,000 ac-ft/y, 583,000 acre-foot per year, and 570,000 acre-foot per year). When compared against the 450,000 acre-foot per year outflow volume of the estuary modeling target distribution, it seems that the system as modeled cannot capture all major runoff events and this implies that available water is still being lost to tide. Further work is needed to assess if it is practical to capture some of these lost waters.

The performance measures used in these analyses are likely to undergo revisions. Ongoing estuarine research may cause modifications in the estuarine performance measures, particularly the modeling performance targets. Since these targets define the available water in the basin, such changes could have a significant impact. The suitability of the water supply criteria also needs further work.

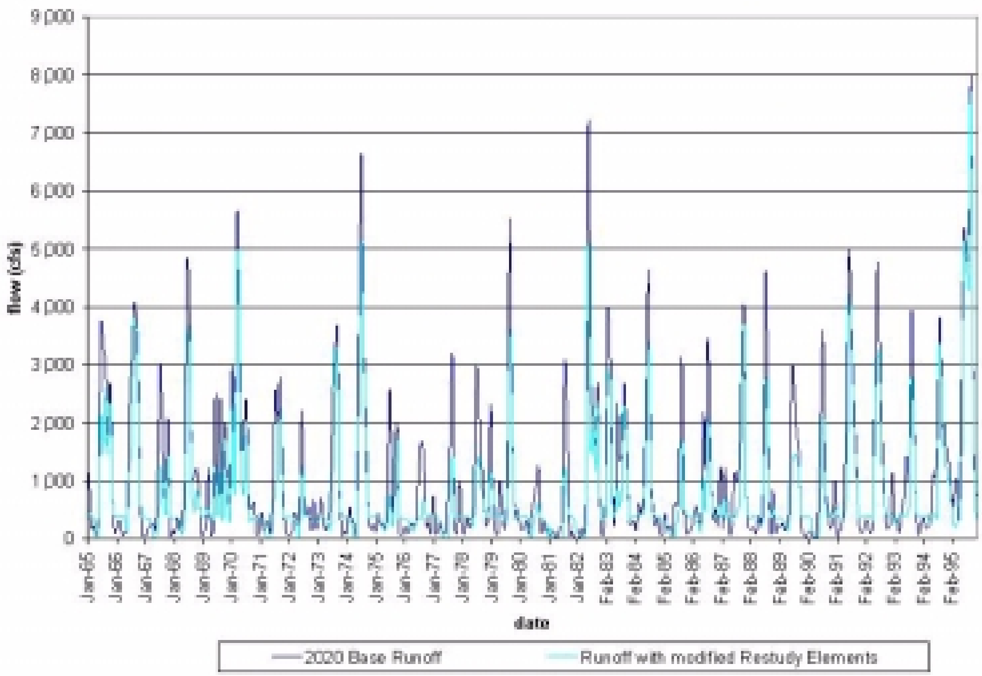

Figure I-8. Estuarine Performance for Assessment #3.

The revised demands and runoff used here are considered to be an improvement over previous estimates. Better and more detailed hydrologic modeling is still required for this basin.